Effect of thermal and non-thermal treatment on the quality of tomato ready to serve (RTS) beverage

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***Abstract*—The investigation was aimed to study the effect of thermal (70, 90 °C for 1 min) and high pressure processing (HPP, 400-500 MPa, 150s) on the product quality parameters, specifically browning index, colour difference, total plate count (TPC), yeast and mold count (Y&M) and lycopene content in tomato ready to serve (RTS) beverage. Untreated tomato RTS beverage was used as control and had 4.12 mg/100 ml lycopene, 91.24 browning index, 2.36 log CFU/ml TPC and 2.42 log CFU/ml Y&M count. The content of lycopene in thermal and HPP treated tomato RTS beverage did not significantly differ from that in untreated (control) sample. Significant increase in colour difference and browning index was observed after thermal treatment but not after HPP treatments. HPP treatment at 500 MPa for 150 s leads to 1.77 log reduction in TPC, with no Y&M detected in tomato RTS beverage. These results indicate that high pressure processing can be used as an alternative to thermal processing to produce microbiologically safe tomato RTS beverage while preserving quality of the product.**

***Index Terms*— Tomato, thermal processing, high pressure processing, microbial quality.**

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L) member of the *Solanaceae* family, is one of the most consumed vegetable worldwide and important source of bioactive compounds (tocopherols, polyphenols, phenolics, carotenoids), vitamins, fibers and minerals. Various epidemiological studies have reported the potential role of tomato phytochemicals in prevention of blindness, cardiovascular diseases (CVD), respiratory disorders, and some forms of cancers (Rao and Rao 2007, Cuevas-Ramos et al. 2013). Tomatoes are consumed both in fresh and processed form and more than 80 per cent of processed tomatoes are consumed in the form of paste, puree, tomato juice, sauce and catsup (Gould, 2013). However tomato based beverages are less available in the market. Considering the benefits of tomatoes, it can be used to develop a ready to serve beverage in combination with other additives for direct consumption.

Conventional thermal processing remains the most adopted technology for preservation of tomato based products, but high temperature leads to browning reactions, color change, vitamin loss and an overall loss of nutritional and sensorial value of the tomato products. In current global market, consumers demand for minimally-processed food products have encouraged food industries interest in non-thermal processes for food processing and preservation (Jan et al. 2017). Among the alternative preservation technologies, high pressure processing (HPP, 400–600 MPa) at chilled or elevated temperature has scientifically and commercially demonstrated to deliver microbial safe high quality stable product (Balasubramaniam et al. 2015).

Previous researches on the effect of HPP in tomato products were limited to tomato paste, tomato juice or tomato pulp (Yan et al. 2017), while impact of HPP on the quality of tomato based ready to serve (RTS) beverage was not reported. Therefore, the objective of this study was to evaluate the effect of thermal and HPP on quality of tomato RTS beverage.

2. RESEARCH METHODOLOGY AND MATERIAL USED

2.1. Tomato RTS beverage preparation

Based on preliminary trials, tomato RTS beverage of following formulation i.e. 12.5 per cent tomato paste (32 °Brix), 22.16 per cent sugar syrup (34 °Brix), 0.08

per cent citric acid, 0.87 per cent salt and 64.39 per cent water was selected and subjected to further thermal and HPP processing.

2.2. Conventional thermal processing

Beverage samples were placed in stainless steel vessel and pasteurized at 70 and 90 °C for 1 min in a water bath, cooled to 50°C and filled in PET bottles under aseptic environment of laminar air flow and stored at 4 °C until analysis.

2.3. High pressure processing (HPP)

HPP experiments were conducted using batch type high pressure processing system of maximum working pressure of 600 MPa. The system consist of pressure vessel, water reservoir tank, pressure intensifier pump, closures/plug and process control system. Distilled water was used as a pressure transmitting fluid. Samples of beverage were bottled in 200 ml PET bottles and loaded in the pressure vessel (3 liter capacity) and pressurized to 400 MPa, 450 MPa and 500 MPa for 150 s. After the required hold time has passed, the system is depressurized, the products were unloaded, cooled and stored at 4 °C until analysis. The pressure come up time for every operation was between 18-70 s, and decompression time was less than 15 s.

2.4 Total colour change and Browning Index (BI)

Visual colour was measured using Lovibond RT850i CREISS (Cyber Chrome, Inc. Stone Ridge, NY) in terms of L* (lightness), a* (redness and greenness) and b* (yellowness and blueness). The overall colour difference was calculated by total colour change (ΔE*) as quantified by following equation (Raj et al. 2019):

$$\Delta E^* = [(L_1^* - L^{0*})^2 + (b_1^* - b_0^*)^2 + (a_1^* - a_0^*)^2]^{1/2}$$

where, subscript '1' depicts the colour value for treated sample being and '0' depicts the colour value for untreated sample.

BI was calculated according to the following given equation (Palou et al. 1999):

$$BI = [100 (x - 0.31)] / 0.172$$

where: $x = (a^* + 1.75 L^*) / (5.645 L^* + a^* - 3.012 b^*)$

2.5 Microbial analysis

The total plate count (TPC) was determined using nutrient agar as a growth medium (Harrigan 1998) after incubation at 37 ± 0.5 °C for 48 h. Yeast and mold count was determined using potato dextrose agar as a growth medium after incubation at 27 ± 0.5 °C for 3–5 days. The numbers of colony forming units (CFU/ml) were recorded and data is presented in log10 (CFU/ml).

2.6 Lycopene

Lycopene content of the samples were estimated using the method describe in Ranganna (Ranganna 1986).

2.7 Statistical analysis

The statistical significance was computed using one-way-ANOVA and notable difference between means was measured using Duncan's multiple range tests at $p<0.05$ by the IBM SPSS Statistics version 20.

3. RESULTS AND DISCUSSION

3.1 Effect of processing on browning index in tomato RTS beverage

It was observed that heating temperature induced a significant ($p<0.05$) change BI of tomato beverage, whereas effect of HPP was insignificant (Table 1). The BI of untreated tomato beverage was 91.24, which increased to 94.14 and 98.89 after thermal processing at temperature 70 °C and 90 °C respectively, for 1 min holding time. Zhang et al. (2016) reported no significant change in the browning degree (BD) value in carrot juice after HPP treatment at 550 MPa for 6 min, however BD of carrot juice significantly ($p<0.05$) increased by 8.71 per cent after HTST treatment at 110 °C for 8.6 s compared to the control, due to non-enzymatic browning during thermal processing. Hu et al. (2020) observed that the browning degree of jabuticaba juice after thermal processing was more pronounced and significantly increased by 51.2 per cent, while HPP at 200 MPa resulted only 25.6 per cent increase in browning degree of juice. Furfural and 5-hydroxymethylfurfural (HMF) compounds are associated with the browning of the juice and are indicators of quality loss in juice (Rodrigo et al., 2003). Rattanathanalerk et al. (2005) reported that HMF and brown pigment in pineapple juice increased linearly with heating temperature. Pham et al. (2021) found that ascorbic acid is essential to cause browning in an orange juice model system, also higher concentrations of furfural, 3-Hydroxy-2-pyrone, and 2-furoic acid were formed in orange juice when concentration of ascorbic acid was higher. Hence in our study the increase in BI of tomato beverage with increase in temperature may be probably due to degradation of ascorbic acid in beverage and formation of HMF.

Table no. 1- Colour attributes of raw and processed tomato RTS beverage

Parameters	Treatments					
	Control	T1	T2	HPP1	HPP2	HPP3
Colour difference (ΔE)	NA	1.18^{b}± 0.14	4.07^{a}±0.35	0.21^{c} ±0.07	0.22^{c}±0.04	0.29^{c}±0.06
Browning Index	91.24^{c}±1.40	94.14^{b}±0.48	98.89^{a}±1.20	91.31^{c}±1.10	92.37^{c}±0.25	92.69^{cb}±0.29

Treatments: Control: Untreated beverage; T1: 70 °C, 1 min; T2: 90 °C, 1 min; HPP1: 400 MPa, 150s; HPP2: 450 MPa, 150s; HPP3: 500 MPa, 150s.

Values are mean ± standard deviation (n=3), NA: Not applicable

Values in the same row with different letters indicate significant difference ($p<0.05$).

3.2 Effect of processing on the ΔE of tomato RTS beverage

In this study, colour parameters such as L*(lightness), a* (redness), and b*(yellowness) were measured for the untreated, thermally and HPP processed tomato RTS beverage and were used to calculate ΔE. The ΔE characterizes total colour changes in the processed products, from not noticeable (0-0.5), slightly noticeable (0.5-1.5), noticeable (1.5-3.0), and well visible (3.0-6.0) to great (6.0-12.0) (Jez et al. 2020). It was observed that heating temperature induced a significant ($p<0.05$) change in colour (ΔE) of tomato beverage (Table 1). Thermal processing of tomato beverage at 70 °C for 1 min induced slightly noticeable ($0.5< \Delta E <1.5$) colour change in tomato based RTS whereas thermal processing at 90° C for 1 min induced well visible ($3.0 <\Delta E <6.0$) colour change in tomato RTS beverage. During thermal processing L* value decreased while a* and b* value increased, indicating shift in colour of tomato beverage towards dark brown yellow. A decrease in L* values in thermal treated tomato RTS beverage is associated with the formation of dark colour compounds due to non-enzymatic browning reactions (Klim and Nagy 1988), thus reducing the acceptance of RTS beverage. In juice non-enzymatic browning can be due to chemical reactions of amino acids, sugars and ascorbic acids (Bharate and Bharate 2014). Clegg (1964) stated that sugar-amino acid reactions of the classical Maillard type are of minor importance in juices of high acidity (pH 2.0–4.0). Therefore ascorbic acid degradation during thermal processing is the major contributor to the non-enzymatic browning in thermally processed tomato RTS beverage.

On the other hand, HPP induced no noticeable ($0.0< \Delta E <0.5$) change in the colour of tomato RTS beverage at all pressure levels. It was reported earlier that the colour of tomato juice remained unaffected after pressurization at 600 MPa, 45 °C for 5 min (Yan et al. 2017). Liu et al. (2013) found that after HPP treatment of watermelon juice there was non-significant increase in L * values while a * and b * were similar to untreated sample and ΔE value was less than 2 and concluded that HPP was able to maintain the original colour of juice water melon juice. Patras et al. (2009) observed increase in chroma and redness of tomato purees at HPP conditions of 400 MPa and 500 MPa, and colour attributes were well preserved by HPP than thermal treatment (70 °C, 2 min).

3.3 Effect of processing on the microbial quality of tomato RTS beverage

Total plate count (TPC) and yeast and mold (Y&M) count provide a food processor with information on the quality or handling history of raw materials, food processing and storage conditions, and handling of the finished product. Furthermore, they can also be used to determine the shelf-life or forthcoming sensory change in a food product (Yousef and Carlstrom 2003). It was observed that pressure significantly ($p<0.05$) decrease TPC and Y& M count in tomato RTS beverage (Table 2). The initial TPC of untreated sample was 2.36 log CFU/ml. HPP treatment at 450 and 500 MPa for 150 s resulted statistically significant 0.64 and 1.77 log reduction in TPC count, respectively. It was earlier reported by Hsu (2008) that there was 0.9 and 1.5 log decrease in total viable count of tomato juices treated by 300 and 400 MPa for 10 minutes respectively and pressure processing at 500 MPa for 10 min resulted in inactivation of all the microorganisms to a level below the detection limit. Chen et al. (2015) observed that both thermal and HPP (400 and 600 MPa for 10 and 20 min) decreased the total mesophilic bacteria to undetectable level, thus guaranteeing the safety of asparagus juice.

The untreated sample had mean Y& M count of 2.42 log CFU/ml (Table 2). A 0.29 log and 0.54 log reduction in Y& M count was observed in tomato RTS beverage treated at 400 MPa and 450 MPa for 150s respectively. It is well known that higher pressures generally caused higher inactivation of vegetative microorganisms (Considine et al. 2008). Compared to TPC, Y&M count in tomato RTS beverage reduce to below detection limits at 500 MPa for 150 s. The above results indicated that Y& M were more sensitive to the HPP treatment than aerobic bacteria, which was similar to previous work (Vega-Gálvez et al. 2012). It was earlier reported by Chang et al. (2017) that HPP treatment of white grape juice at 300 MPa for 3 min resulted in reduction of 1.1 log CFU/ml in yeast and molds counts whereas HPP at 600 MPa decreased yeast and mold population to level below the minimum detection limit (<1.0 log). Likewise Szwajgier et al. (2022) found that HPP treatment of blend of beetroot and carrot juice at 400 and 500 MPa for 10 and 15 min decrease the initial yeast and moulds load from 1.79 and 1.86 log cfu/ml, respectively, to below of limit of quantification. Calligaris et al. (2012) hypothesized that main mechanism accounting for microbial inactivation by HPP is probably due to the mechanical disruption of cells caused by spatial pressure, velocity gradients, turbulence and cavitation. It was observed that the thermal processing at all temperature and time combination and pressure processing at 500 MPa for 150 s resulted in microbial safe product.

Table no. 2- Microbial quality of raw and processed tomato RTS beverage

Parameters	Treatments					
	Control	T1	T2	HPP1	HPP2	HPP3
TPC	2.36^{a}	ND	ND	2.23^{b}	1.72^{c}	0.59^{d}
Y&M	2.42^{a}	ND	ND	2.13^{b}	1.88^{c}	ND

Treatments: Control: Untreated beverage; T1: 70 °C, 1 min; T2: 90 °C, 1 min; HPP1: 400 MPa, 150s; HPP2: 450 MPa, 150s; HPP3: 500 MPa, 150s.

Values are mean (n=3), ND: Not detected

Values in the same row with different letters indicate significant difference ($p<0.05$).

3.4 Effect of processing on the lycopene content of tomato RTS beverage

Lycopene is the pigment responsible for characteristic deep-red colour of ripe tomato fruits and has been assumed as the chief bioactive carotenoid that facilitates health benefits (Ali et al. 2021). Sharma and Le Maguer (1996) found that skins of tomato contained about five times more lycopene than the whole tomato pulp and concluded that most of the lycopene is found in the insoluble fiber portion of the tomatoes. Fig. 1 shows lycopene content in tomato beverage after thermal and HPP treatment. The total lycopene content of untreated and treated tomato beverage ranged from 4.12 to 4.19 mg/100 ml but showed no significant difference due to processing condition. The thermal treatment did not cause lycopene degradation. These findings are in agreement with Yan et al. (2017) who reported no significance difference in lycopene content of unprocessed and thermal processed (90 °C, 90 s) tomato juice. Earlier studies have found that to induce lycopene degradation in lycopene containing foods severe heat treatment was required (Nguyen et al. 2001, Shi and Le Maguer 2000). Contrary, Odriozola-Serrano et al. (2008) reported 4.67 % increase in lycopene content of tomato juice after thermal treatment at 90 °C for 60 s. These authors hypothesized that heat treatment disrupt cell membrane and protein-carotenoids complex in tomato cell, making lycopene more accessible for extraction.

The lycopene content also did not vary significantly after HPP at 400MPa, 450 MPa and 500 MPa for 150 s. These results are at par to previous studies showing that lycopene content remained stable in tomato juice and tomato puree processed at 600 MPa, 46 °C, 10 min (Yan et al. 2017) and 600 MPa, 20 °C, 12 min (Qiu et al. 2006) respectively. On the other hand, Hsu et al. (2008) reported upto 56 % increase in lycopene content of tomato juice processed at 300-500 MPa for 10 min. Furthermore, Sanchez-Moreno et al., 2006 revealed increase in extractable lycopene and carotenoids as a result of high-pressure treatment (400 MPa, 25 °C, 15 min) of tomato puree.

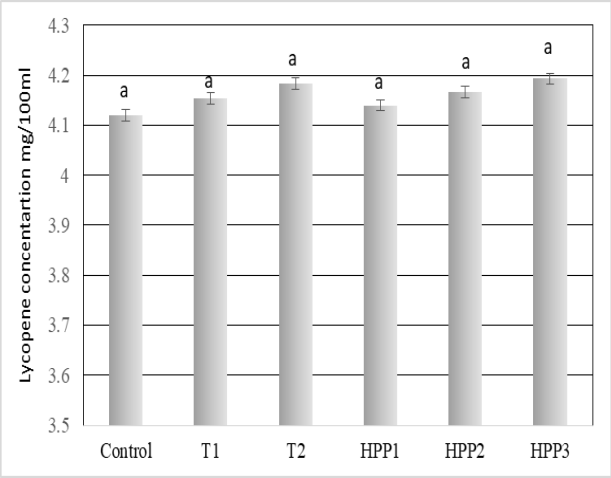

Fig.1 Lycopene concentration in unprocessed and processed tomato RTS beverage

Treatments: Control: Untreated beverage; T1: 70 °C, 1 min; T2: 90 °C, 1 min; HPP1: 400 MPa, 150s; HPP2: 450 MPa, 150s; HPP3: 500 MPa, 150s.

Values are mean (n=3)

Values with different letters indicate significant difference ($p<0.05$)

4. CONCLUSION

In this study both thermal and HPP treatment had no effect on the lycopene content of tomato RTS beverage. Thermal processing induced more colour and browning change ranging between 1.18 to 4.07 and 94.14 to 98.89, respectively in tomato RTS beverage. Microbiologically safe (TPC < 1 log10 CFU/ml and Y&M were not detected) tomato beverage was achieved after HPP treatment at 500 MPa for 150s and thermal treatments. Therefore a 500 MPa treatment can be useful in producing microbiologically safe high-quality tomato RTS beverage as an alternative to thermal processing.

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